(NASA-CR-161268) [AUTOMATED SEMICONDUCTOR DIFFUSION AND OXIDATION FACILITY] Final Report (Tylan Corp., Torrance, Calif.) 8 p HC A02/MF A01 CSCL 07D

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NASA Contract NAS8-31612

Final Report

I System Overview

The concept of this project was to develop a semiconductor diffusion and oxidation facility which was totally automated. Wafers would arrive at the facility on an air track,be automatically loaded into a furnace tube, processed, returned to the track, and sent on to the next operation.
The entire process was to be controlled by a computer. Installation took place at NASA, MSFC, Huntsville, Alabama. NASA supplied the two 3-stack furnaces and the facility. Tylan supervised installation and checkout at Huntsville.
It was desired to demonstrate the following diffusion processes:

1. Wet and dry oxidation for general use.
2. Wet and dry oxidation for gate oxide.
3. Boron diffusion.
4. Phosphorous diffusion
5. Sintering

Part of the facility consisted of state-of-the-art components and processes, such as the diffusion furnace and high temperature grown oxide. However, there were several major innovations that this contract sought to demonstrate. These were:

1. A process controller specifically designed for semiconductor processing.
2. An Automatic loading system to accept wafers from an air track, insert them into a quartz carrier, then place the carrier on a paddle for insertion into the furnace.
3. Automatic unloading of the wafers back onto the air track.
4. Boron diffusion using diborane with $\pm$ 5% uniformity.

With the submittal of this report, all nineteen pages of the Scope of Work have been completed with the exception of boron diffusion. Installation of the system was initially delayed by facility problems and this led to conflicts in scheduling between NASA and the contractor. As a result, requirements were demonstrated at MSFC, but the system has not been run in a production mode as of this date. Accordingly, no experience is available on the productivity of the design; however, enough data has been gathered to suggest several improvements in future systems:

I System Overview (continued)

1. The Monitrol process controller is a first generation real-time controller for semiconductor processing. It has several shortcomings which have been identified--particularly in flexibility and capacity. A second generation system, called the Tycom 900, has been designed and put into production. It is proving to be superior to the Monitrol, overcoming all known problems in the MSFC installation. It should be used in the future.

2. A major problem encountered in the subject facility was the technique of rotating the quartz carrier 90° and laying it on the paddle. This was accomplished by a separate microprocessor control which worked from limit switch inputs. Although it worked within specified limits, the design was awkward, involved many parts and may require maintenance. This function can be better regulated by the new generation Tycom 900.

3. Boron diffusion using diborane is probably not possible at the present level of technology. Many different techniques and equipment variations were tried in order to make diborane diffusion successful, but to no avail. The process should be converted to solid boron diffusion or to boron tribromide.

4. The air track occasionally allowed wafers to "hang up". The adjustment to keep this from happening is rather critical. It is believed that this problem can be overcome with a modest development program.

II Operation

The overall diffusion facility consisted of the following:

1. Two existing (at Huntsville) Thermco 3-stack diffusion furnaces.
2. Two special load stations which incorporates a wafer track and buffer tee.
3. Two automatic wafer boat elevation systems.
4. Six automatic wafer boat insertion systems.
5. A computer-based process controller.
6. Two source cabinets for the gas blending systems.
7. Eight Max I boat loaders.
8. Six gas blending assemblies.
9. Expendable materials (quartz, silicon carbide, etc.)

Wafers arrive at the load station on a wafer track and are temporarily stored in a buffer-tee until required for loading into the furnace. When a furnace

II Operation (continued)

is ready, the wafers are sent along the track to a load station where a vertically-oriented quartz carrier holding 25 wafers is located. The wafers are loaded into the carrier which is then lifted by an automatic "claw" mechanism above the furnace to be used. Next, the silicon carbide paddle is retracted from the furnace under the suspended carrier. At the proper time, the carrier is lowered onto the retracting paddle as the paddle retracts until it is lying horizontally on the paddle. The claw opens and retracts upward. The paddle goes into the furnace, carrying the wafer boat and its load of 25 wafers, then the process begins. The control of all functions except the lowering of the wafers carrier on the paddle is accomplished by the Monitrol Process Controller. Carrier loading is directed by a separate microprocessor-based controller.
Recipes for various processes are stored in the Monitrol. This unit contains a DEC PDP-8 minicomputer. It has complete manual backup of all functions as well as visual indication of operating state. It may be interfaced with an upstream computer for management data presentation.

III Documentation

Tylan has submitted all the required documentation to operate the system. Attached is a complete drawing list for reference. Also attached is a photograph of the equipment.

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SEQUENCE OF OPERATION OF THE AUTOMATIC

LOADING STATION

A. LOADING SEQUENCE

1. Push BT RQST (X).
2. Horizontal B.P. (X) starts to pull and hits the out L.S. (S), B.P. (X) stops.
3. Claw opens, the vertical B.P. starts to come down.
4. It hits the vertical L.S. (X). The position L.S. on the claw is activated, the vertical B.P. stops.
5. Claw closes and the vertical B.P. starts going up with the boat.
6. Position L.S. is deactivated and horizontal B.P. (X) starts to push until the position L.S. is activated again, then it stops. The vertical B.P. is moving up all the time and the operation repeats until the horizontal B.P. hits the center L.S. (X).
7. The vertical B.P. goes up in a faster pace and the horizontal B.P. (X) continues to push in.
8. The vertical B.P. hits the uppper L.S. and stops.
9. The horizontal B.P. (X) hits the in L.S. (X) and stops.
10. The vertical B.P. starts coming down.
11. It hits the B.T. limit switch and slows down.
12. It places the boat in the B.T. and the boat handle activates the position L.S. on the claw.
13. The claw opens and the carriage starts to go down with the boat.
14. The carriage stops at the bottom of the B.T.
15. The other B.T. starts to send wafers.
16. The wafer is caught in the boat and the carriage indexes up one slot.
17. The operation repeats until all wafers are received.

18. The carriage moves to the upmost position.

19. The claw closes and picks up the boat.

20. The vertical B.P. starts to go up until it hits the upper L.S. and stops.

21. The horizontal B.P. (X) starts to pull out.

22. It hits the middle L.S. (X) and stops.

23. The vertical B.P. starts to come down slow.

24. It places the boat onto the paddle and stops when the position L.S. on the claw is activated.

25. The horizontal B.P. (X) starts to pull out very slowly.

26. When the position L.S. deactivates, the vertical B.P. starts to drop again.

27. Operation repeats until either:

    a) The horizontal B.P. (X) hits the out L.S. (X) and stops. The vertical B.P. continues to come down until it hits either the position L.S. or the vertical L.S. (X) and stops.

    b) The vertical B.P. hits the vertical L.S. (X) and stops The horizontal B.P. (X) stops at the same time.

28. Claw opens up and the vertical B.P. goes up to the top limit position.

29. The horizontal B.P. (X) starts to push in with the boat until it hits the in L.S. (X).

B. UNLOADING SEQUENCE

1. Push PCS END (X).

2. Same as A-2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13.

3. When the air sensor senses the wafer, the carriage stops and sends out a wafer.

4. The operation repeats until all the wafers are sent.

5. Same as A-14.

6. Same as A-18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28 and 29.

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DIFFUSION PROCESS SYSTEM

DPS - 1010

3874-010	INSTALLATION DRAWING	E		10- 7-76
3874-021	SCHEMATIC, INPUT & OUTPUT BDS.	E	3-shts	9 -24-76
3874-022	SCHEMATIC, INPUT BD.	E	3-shts	9 -24-76
3874-023	INTERFACE BD. ASS'Y	C		9 -27-76
3874-024	WIRING SCHEMATIC, E.E. BOX	E		9 -29-76
3874-025	NASA PROM BD.	D		9 -29-76
3874-026	WIRING & SCH. HZ BOAT PUSHER	C		10-18-76
3874-027	WIRING SCH. POSITION SW. HORT.	C		10- 1-76
3874-028	WIRING & DWG. TEMP. CONTROLLER	C		10-15-76
3874-029	WIRING DWG. VERTICAL DRIVE	D		10-18-76
3874-030	SCHEMATIC, BOAT PUSHER, SPEED CONT.	D		10-18-76
3874-031	COMPUTER INTERFACE BD. NASA I	D		4 -26-78
3874-040	WIRING DIAG. HORT. BOAT PUSHER	C		8 -19-76
3874-041	SERIAL INTERFACE CONN. NASA I	B		4 -25-78
3874-100	PARTS LIST GPS-1010-1	B		3 -25-76
3874-101	FRAME ASS'Y	E	3-shts	3 -25-76
3874-102	SIDE DOOR ASS'Y	D		3 -25-76
3874-103	FRONT DOOR ASS'Y	D		3 -25-76
3874-104	TOP ASS'Y	C		3 -25-76
3874-105	REAR ASS'Y	D		3 -25-76
3874-106	SOURCE CAB. ASS'Y, RIGHT HD.	D		3 -25-76
3874-107	SOURCE CAB. ASS'Y, LEFT HD.	D		3 -25-76
3874-108	HEAT SHIELD	C		3 -25-76
3874-109	MONITROL CABINET ASS'Y	E		4 -28-76
3874-110	PANEL, PAPER TAPE READER	D		6 - 1-76
3874-111	INPUT & OUTPUT BD. ASS'Y	C		8 - 3-76
3874-112	PROCESS TUBE, CROSS FLOW	E		7 -12-77
3874-113	INPUT & OUTPUT BD. ASS'Y	C		6 -27-78
3874-121	DETAIL, LOAD STATION	E	3-shts	5 - 6-76
3874-122	BRACKET, SUPPORT SHAFT BEARING	C		4 -20-76
3874-123	FRONT PANEL, BOAT PUSHER	C		4 -20-76
3874-124	FRONT PANEL, VERT. DRIVE	C		4 -20-76
3874-126	SHAFT, SUPPORT	C		4 -20-76
3874-127	SHAFT, VERT. DRIVE	C		4 -20-76
3874-128	ACCESS PANEL	C		4 -20-76
3874-129	BRACKET, SUPPORT SHAFT	C		4 -20-76
3874-131	HORT. DRIVE SWITCH BRKT.	B		5 -17-76
3874-132	HORT. DRIVE SUPPORT MTG. PLATE	B		5 -17-76
3874-133	HORT. DRIVE COVER	D		5 -17-76
3874-134	COVER, VERT. DRIVE	D		5 -17-76
3874-135	SUPPORT, SHAFT, VERT. DRIVE	C		5 -17-76
3874-136	PLATE, SWITCH MTG. VERT. DRIVE	B		5 -17-76
3874-137	BRACKET, SW. MTG., VERT. DRIVE	B		5 -17-76
3874-138	PLATE, GUIDE, VERT. DRIVE	B		5 -17-76

NAS 8-31612 DIFFUSION PROCESS SYSTEM DPS-1010 (continued)

3874-142	BOAT, AUTO-LOAD	D	7 -14-76
3874-143	PANEL ENCLOSURE MODIFICATION	C	9 - 2-76
3874-144	HEAT SHIELD	C	5 -17-76
3874-145	AIR STRIP	D	5 -20-76
3874-146	BASE PLATE, CORNER	D	5 -20-76
3874-147	CORNER PLATE	C	5 -20-76
3874-148	BASE PLATE, WAFER CARRIER	C	5 -20-76
3874-149	HOLDER, AIR STRIP	C	5 -20-76
3874-150	OUTER CORNER GUIDE	C	5 -20-76
3874-151	INNER CORNER GUIDE	B	5 -20-76
3874-152	GUIDE STRIP	B	5 -20-76
3874-153	CARRIER SIDE, OUTER	C	5 - 6-76
3874-154	CARRIER SIDE, INNER	C	5 - 6-76
3874-155	BRACKET, CARRIER SIDE	C	5 - 6-76
3874-156	SHAFT 25IN, VERT. DRIVE	B	5 -17-76
3874-158	BRACKET, SPEED CONTROL	C	8 - 2-76
3874-159	COVER, SPEED CONTROL	C	8 - 2-76
3874-160	SHAFT, SPEED CONTROL	B	7 -22-76
3874-169	CHASSIS, CONTROL LOGIC	D	6 -10-76
3874-170	SUPPORT	C	5 -27-76
3874-171	GUIDE, VERTICAL - WAFER BOAT	D	6 -23-76
3874-172	GUIDE BLOCK, FRONT	B	6 -23-76
3874-173	E/E COMPT.	D	8 -19-76
3874-174	W/D - VERTICAL DRIVE ASSEMBLY	C	3 -14-77
3874-175	GUIDE, WAFER CARRIER	C	6 -17-76
3874-176	BRACKET, WAFER CARRIER	C	6 -17-76
3874-177	WHEEL, WAFER CARRIER	B	6 -17-76
3874-179	CLAMP, NARROW FLANGE	C	6 -18-76
3874-180	CLAMP, WIDE FLANGE	C	6 -18-76
3874-181	SHAFT, CLAMP	C	6 -18-76
3874-182	EXTENSION, SHAFT	B	6 -18-76
3874-183	BRACKET, SWITCH MTG.	B	6 -18-76
3874-184	BUMPER, ACTUATOR	B	6 -18-76
3874-185	BRACKET, INLET	C	6 -21-76
3874-186	PAD, VERTICAL	B	6 -23-78
3874-187	GUIDE BLOCK, REAR	B	6 -23-78
3874-188	PLATE, SLIDE MTG.	B	6 -29-76
3874-189	ANGLE, SIDE MTG.	C	6 -29-76
3874-190	PANEL, CONN.	C	6 -28-76
3874-191	FRONT PANEL, E/E, COMPT.	C	6 -27-76
3874-192	ADAPTER, FRONT GUIDE BLOCK	B	7 -14-76
3874-193	SPUR GEAR MODIFICATION	B	7 -14-76
3874-162	CONDUIT, VERT. DR.	C	5 -17-76